Validation Plan
(of GOSAT TANSO Standard Products)

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Definition of validation

Validation
to evaluate uncertainties of GOSAT products with other data of less uncertainties acquired independently

Comparison
to evaluate GOSAT products with observation data with equivalent uncertainties or data estimated by simulation models

Calibration
to evaluate L1 product which is performed mainly by JAXA

Uncertainty=$\sqrt{(\text{accuracy})^2 + (\text{precision})^2}$
Basic Concept of GOSAT Validation

- The priorities of standard product validation and comparison have been set as follows:
  1. L2 SWIR CO₂ and CH₄ column abundances
  2. L2 TIR CO₂ vertical profile of concentration
  3. Global distributions of L3 SWIR CO₂ and CH₄ column abundances
  4. Global distribution of L4A CO₂ flux
  5. Global distribution of L4B CO₂ concentration
Strategy for validation of GOSAT CO₂ and CH₄ column abundances

- **Requirement for observation equipments**
  - Well established observation technology
  - Small uncertainty; CO₂ less than 1% (0.3% preferable), CH₄ less than 2%

- **Measurement technique to validate these products**
  - Absorption technique of solar direct radiation by ground-based high-resolution FTS (0.05-0.015 cm⁻¹) and mobile FTS (around 0.2 cm⁻¹)
  - Aircraft in situ measurement (e.g. JAL project data)

To validate TIR products, vertical profiles of temperature, pressure, and water vapor obtained by Rawin Sonde are useful.
Methodology of validation of L2 products

- **Collect data at various conditions**
  - Albedo: grassland, forest, desert, snow surface, urban, sea surface
  - Terrain: flat or complex
  - Aerosol: sea salt, dust, artificial sulfuric acid, black carbon, organic carbon
  - Cirrus: thick or thin
  - Water vapor: high or low
  - Continuously observing sites (ground-based high-resolution FTS: about 10 sites, JAL project: 10 airports) for validation (under consideration)

  ※Considering points: required quality level and cost effective

- **Set up necessary instruments at continuously observing sites**
  - (e.g. FTS, lidar and sky radiometer)

- **Evaluation of spatial and temporal characteristics at each FTS site**
  - Identify the accuracy of GOSAT L2 products
    - (It will take much time for evaluating the bias. 3 months for Lauder?)
  - Grouping (cirrus, aerosol, water vapor, albedo and etc.)

- **Other methods**
  - e.g. Trajectory analysis, Regional CO₂ forward model
# Error factors in deriving XCO$_2$ and XCH$_4$

<table>
<thead>
<tr>
<th>Priority</th>
<th>Error factor</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>**</td>
<td>Characteristics of TANSO FTS (e.g. SNR)</td>
<td>Calibration</td>
</tr>
<tr>
<td>**</td>
<td>Aerosol</td>
<td>Validation</td>
</tr>
<tr>
<td>*</td>
<td>Thin cirrus</td>
<td>Validation</td>
</tr>
<tr>
<td>*</td>
<td>Surface pressure (elevation)</td>
<td>Validation</td>
</tr>
<tr>
<td>*</td>
<td>Profiles of P, T and R.H.</td>
<td>Validation</td>
</tr>
<tr>
<td>*</td>
<td>Absorption line</td>
<td>Algorithm</td>
</tr>
<tr>
<td>*</td>
<td>Fraunhofer line</td>
<td>Algorithm</td>
</tr>
<tr>
<td>*</td>
<td>Surface albedo (sunglint reflectance)</td>
<td>Validation</td>
</tr>
</tbody>
</table>

**: the top priority, *: the second priority.
Schematic illustration of validation experiments

Source: GOSAT pamphlet
The uncertainty of the ground based high resolution FTS (Park Falls)


- The precision of FTS column CO₂
  - Clear day → about 0.1%
  - Partly cloudy day → about 0.2%

- The bias of FTS column CO₂ compared to integrated aircraft profiles
  - less than 2%

- The uncertainty of FTS column average CO₂ VMR after calibration
  - about 0.3% (±1.1 ppmv) at SZA less than 60 deg

The high resolution FTS is useful for GOSAT validation. It is necessary to calibrate the FTS at validation sites.
TCCON is indispensable for GOSAT validation

TCCON: Total Carbon Column Network
(http://www.tccon.caltech.edu/index.html)
# Observation plan of cloud and aerosol parameters at some potential FTS sites for GOSAT validation

<table>
<thead>
<tr>
<th>Instrum. Site</th>
<th>FTS</th>
<th>Lidar</th>
<th>Sky Radiometer</th>
<th>Sun Photometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tsukuba</td>
<td>Bruker 120HR (NIES)</td>
<td>Observed by NIES &amp; MRI</td>
<td>Observed by MRI</td>
<td>None</td>
</tr>
<tr>
<td>Moshiri</td>
<td>Bruker 120HR (Nagoya U.)</td>
<td>To be installed</td>
<td>To be installed (NIES’s)</td>
<td>None</td>
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<tr>
<td>Lauder</td>
<td>Bruker 120HR (NIWA)</td>
<td>To be upgraded (MRI &amp; NIES)</td>
<td>None</td>
<td>CSD Middleton SP02 (ABM)</td>
</tr>
<tr>
<td>Bremen</td>
<td>Bruker 125 HR (U. Bremen)</td>
<td>Seeking the fund to install</td>
<td>To be installed (NIES’s)</td>
<td>None</td>
</tr>
<tr>
<td>Darwin</td>
<td>Bruker 125 HR (ARM site)</td>
<td>Small power lidar</td>
<td>None</td>
<td>Cimel (ARM site)</td>
</tr>
<tr>
<td>etc.</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Lidar: two-wavelength polarization lidar
The site conditions of Tsukuba FTS
The site conditions of Tsukuba FTS
Ground-based NIR FTS at Tsukuba

- Observation site
  National Institute for Environmental Studies (NIES), Tsukuba, Japan
  (Latitude 36.1° N, Longitude 140.1° E, Altitude 31 m)

- FTS: Bruker IFS 120 HR
  - Beam splitter: CaF$_2$
  - Detector: InSb (1,800–10,500 cm$^{-1}$)
    Si diode (9,200–14,000 cm$^{-1}$)
  - Instrument resolution: 0.05–0.0035 cm$^{-1}$
  - Observation time: ~10 min

- In 2001, measurements of atmospheric constituents related with the destruction of the ozone layer were started in MIR region.

- In 2004, optical components of the FTS were replaced for measuring greenhouse gases such as CO$_2$ and CH$_4$ in NIR: optical filters, CaF$_2$ beam splitter, and InSb detector.

However, in the present, measurements with the NDSC #1, #2, and #3 optical filters are also in operation.

※NIES NIR FTS will be joined to TCCON
Airborne observation data is very useful for GOSAT validation.

JAL flight routes of CO$_2$ observation and destination airport. The numbers indicate the number of vertical profiles over each airport from November 2005 to April 2007.

Machida, Matsueda and Sawa, 2007(IGAC Newsletter)
Vertical CO₂ profiles obtained by CME on board aircraft (JAL) around Narita and Jakarta airport

Similar profiles: Nagoya, Kansai

Similar profiles: Sydney, LA

Machida, Matsueda and Sawa, 2007 (IGAC Newsletter)
Data for estimation of $X_{CO_2}$

- In situ CO$_2$ data obtained by descending JAL aircraft (1,500~12,418 m) (Narita airport 2006/10/26)
- Tateno rawin sonde data
  - PBL height: 1,000 m
  - Tropopause height: 17,227 m
- CO$_2$ data from ground to PBL
  - In situ data of MRI/JMA tower (200m) (by Machida)
- CO$_2$ data above 20km
  - Assumed nearly equal to the average value in troposphere 5 years ago (371.7 ppm)

$X_{CO_2} = 380.079$ ppm
Validation for GOSAT sunglint observation

Observation area: Sagami-bay (35.0-35.1°N, 139.2-139.4°E)
Sampling altitude: 0.5, 1, 1.5, 2, 3, 4, 5.5, 7 km
Sampling method: Flask sampling → Nadir
Observation schedule: every 2 weeks

[T. Machida, NIES]

Beechcraft 200T
Validation of aerosol and cirrus cloud

- Error factors to the column abundance
  - Aerosol and thin cirrus cloud
  - It is necessary to observe these factors with CO₂ and CH₄ column abundances at the same time.

- Lidar
  - Derive the vertical distributions of aerosols and thin cirrus clouds with a range resolution of 15 m.
  - Derive depolarization ratio with high accuracy, and discriminate liquid and solid particles.

- Skyradiometer
  - Derive optical depth, particle size distribution and phase function with measurements of direct solar radiation and forward scattering.
  - Derive Single-scattering albedo and phase function with these parameters.

To validate TANSO-CAI, measurements by lidar and skyradiometer are useful. SKYNET and AERONET data are also important for GOSAT validation.
Summary

• Ground-based high resolution FTS data are indispensable for validation of CO$_2$ and CH$_4$ column abundances retrieved from GOSAT data.
• Airborne in-situ measurement data are also important for validation of column abundances and vertical profiles of CO$_2$ and CH$_4$.
• Aerosol and thin cirrus cloud measurements at FTS sites are necessary to validate and improve GOSAT CO$_2$ and CH$_4$ column abundances.